TIME-TEMPERATURE-STRESS CAPABILITIES OF COMPOSITE MATERIALS FOR ADVANCED SUPERSONIC TECHNOLOGY APPLICATIONS

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1.0 INTRODUCTION

This report summarizes the recent progress on Phases II, III and IV of contract NAS 1-12308. This work is under the technical direction of Mr. Bland Stein.

2.0 PHASE II

2.1 Thermal Aging. In Phase I of the test program thermal aging exposures were conducted on B/E, G/E, G/PI, and B/Al for time periods up to and including 10,000 hours. For the B/E, G/E, and G/PI systems additional specimens had been prepared and placed in the thermal aging furnaces at the beginning of Phase I for removal during Phase II at 25,000 and 50,000 hours. As no such provision had been made for the B/Al system a number of these specimens were prepared and placed in the aging furnaces at the beginning of Phase II. The B/Al specimens were to be aged for 25,000 and 40,000 hours. The 40,000 hour figure was chosen so that all the specimens would complete the thermal aging exposures at about the same time period. Aging temperatures and pressures for the resin matrix systems were identical to those used in Phase I. For B/Al the 561K (550°F) age was retained, the 700K (800°F) age was discontinued because of the severe degradation after 10,000 hours, and the 450K (350°F) age was changed to 505K (450°F) to match the flight simulation exposure temperature.

With the completion of the 40,000 hour B/Al exposures the Phase II thermal aging task has been finished. The following section presents and discusses the experimental results of the 40,000 hour B/Al thermal aging exposures.

Thermal aging was conducted on unidirectional and $[0° \pm 45°]_s$ crossplied laminates of B/Al in one atmosphere air at temperatures of 505K (450°F) and 561K (550°F). Following aging, residual tensile and interfiber shear tests were performed at room temperature. Longitudinal tensile strengths of the unidirectional and crossplied materials were determined to evaluate fiber degradation while transverse tensile and longitudinal shear properties of the unidirectional material were obtained to study matrix effects. All data including that from Phase I are presented in Tables 1 through 4.

As discussed in an earlier report (Progress Report, 1 June 1982) the B/Al material used for the 25,000 and 40,000 hour exposures was from a different batch than was used for the Phase I exposures. The Phase II material shows considerably better retention of longitudinal tensile strength for both layups as shown in Tables 1 and 2. The transverse tensile and interfiber shear results, on the other hand, agree more closely with the Phase I data. This indicates that the major material difference involves the boron fiber and/or fiber-matrix interface rather than the aluminum alloy matrix.

Failed specimens from both the 25,000 and 40,000 hour exposures will be metallographically examined (both optical and SEM) in an attempt to identify the degradation mechanisms.

2.2 Flight Simulation Testing. Table 5 shows the status of the flight simulation progress for both the Phase II B/5505 boron/epoxy, A-S/3501 graphite/epoxy, HT-S/710 graphite/polyimide, and boron/aluminum systems and the Phase III Celion 6000/LARC-160 graphite/polyimide system. Testing was halted for about a month in late 1982 because of problems with the Metrascope, the primary monitor and limit detect safety system for the simulation apparatus. Because of the many years of almost continuous operation the device required extensive repair and replacement of several components. Since resuming operation the simulator has performed exceedingly well. For the past 35 week period the average run time has been 155 hours per week (168 hours is the maximum).

Four specimen failures occurred during this reporting period. All were B/Al, three crossplied and one unidirectional. The specimen numbers and failure times were the following:

EC92-1	29,327 hr.
EC92-5	30,477 hr.
EC92-2	31,447 hr.
EU92-2	31,584 hr.

The test plan, as originally proposed, for the long-term flight simulation program was to expose 10 specimens of each material system for 10,000 hours in Phase I and 10 additional specimens for 50,000 hours in Phase II. A modification was made to the test plan for Phase II by adding three more unnotched specimens of each material/orientation combination that would be exposed for 25,000 hours.

Because of the high failure rate of the G/E Specimens and the extensive visual degradation of the B/E specimens, during Phase I, it became necessary to further modify the Phase II plan. All of the original B/E and G/E flight simulation specimens were removed, and new specimens were fabricated to replace them. These specimens were all unnotched.

The maximum test temperature during flight simulation testing of B/E and G/E was reduced from 408 K (275°F) to 373 K (212°F). This temperature was determined from a log time versus 1/T plot of G/E thermal aging data obtained earlier in the program. The curve represents the time/temperature combinations at which significant degradation of the epoxy matrix begins. Extrapolation of the curve to 50,000 hours gave the new test temperature.

During the past reporting period the replacement specimens of B/E and G/E completed 25,000 hours of flight simulation exposure at 373 K (212°F). All of the specimens survived the 25,000 hours without fracture. The condition of the specimens was excellent. There were no loose surface fibers and no edge cracks or delaminations as had been observed on the Phase I specimens exposed at 408K (275°F) for much shorter periods of time. Distinct color changes were visible on the B/E specimens at the heated zones on both sides. Color changes on the G/E specimens were very slight. Examination of the surface of the specimens at 20X magnification revealed a network of fine cracks in the heated zones of both sets of specimens. In general, the 25,000 hour specimens were very similar in appearance to the specimens which had been removed after 10,000 hours of exposure.

The residual strength test plan for the two materials is shown in Table 6. In keeping with the rationale of Phase I, tensile and fatigue and short beam shear specimens were machined from material which was not shielded by the compression stiffening grids. For the compressive specimens the entire width of the flight simulation specimens was used. To get sufficiently thick specimens for comprssive and short beam shear testing it was necessary to bond several layers together. The compressive specimens required four layers (24 ply), and the short beam shear required three layers (18 ply). Specimen preparation techniques, configurations, and test procedures were identical to those used during Phase I.

Residual tensile, compressive, and short beam shear data before and after 25,000 hours of flight simulation exposure are listed in Tables 7 and 8 for B/E and Tables 9 and 10 for G/E. Elastic modulus values are included for the tensile and compressive tests. Also listed are the 10,000 hour residual strength data for the two systems. Fatigue testing has not been completed because of doubler problems. Earlier testing had shown that retaining the titanium doubler from the 3 inch wide flight simulation specimen when cutting the 1/2 inch wide tensile and fatigue specimens resulted in premature doubler bond failures on the titanium end. The procedure that gave the best results was to remove the titanium doublers, cut the 1/2 inch wide by 9 inches long tensile and fatigue specimens, and bond on fiberglass doublers. For the 25,000 hour G/E specimens , removal of the titanium doublers caused some damage to the outer [0°] plies of the specimens. This in turn led to failures (under the doublers) at loads well below those required to fail the undamaged material. A solution to the problem was to cut the tensile and fatigue specimens at the edge of the doubler at the damaged end and bond on new doublers. The new doubler, 2 inches long, covers half of the heated zone of the flight simulation specimen. Specimens of this type were used successfully for the B/Al short term flight simulation residual strength tests (see Figure 12-30, p. 12-44 in the Phase I Final Report). The results of the G/E tensile tests on the original specimens and the two that failed in the damaged areas and were cut and redoubled and then retested are shown below.

	Tensile Strength, MN/m^2 (ksi)	
Specimen No.	Original Test	Retest
B941-1	632 (91.7)	-
-2	479 (69.5)	647 (93.8)
-3	422 (61.2)	583 (84.6)

The tensile results on the two retested specimens indicated that this specimen configuration was satisfactory, and the fatigue specimens were prepared in the same manner. Fatigue tests are in progress, and the results will be presented in the next report.

As shown in Table 7, the tensile strength of the B/E material was lowered approximately 10 percent by the 25,000 hours of flight simulation exposure. The G/E material behaved even better with essentially no change in the tensile strength as a result of the exposure. Modulus values were decreased for both systems by about 10 percent. The effect of the 25,000 hours of flight simulation exposure on the matrix properties, compressive and shear, were slight for the G/E but substantial for the B/E system. Compressive and shear strength of the B/E decreased by about one third after 25,000 hours of cycling. The G/E showed no change in compressive strength and a seven percent loss in shear strength.

In summary of these data, the B/E and G/E systems survivied 25,000 hours of flight simulation exposure at a cruise temperature of 373K (212°F) with little visual damage. Some microcracking of the surface was observed in the heated zones but was not thought to be serious. Mechanical property degradation was minimal for the G/E material. For the B/E system, however, a thirty percent decrease in compressive and shear strengths and a ten percent decrease in tensile strength were observed.

3.0 PHASE III

3.1 Thermal Aging. A thermal aging study of Celion 6000/LARC-160 graphite/polyimide was conducted at 450K (350°F) and 505K (450°F) for time periods out to 10,000 hours. Both 1 atmosphere and 0.014 MN/m^2 (2 psi) exposures were included. Post aging evaluation consisted of weight change measurements, 450K (350°F) tensile tests, and metallographic and SEM examinations.

The appearance of the specimens was relatively unchanged by the 10,000 hours of exposure. Some slight color changes and slight changes in the ring when the specimens were dropped were observed. After 5000 hours some edge cracking had occurred in the specimens aged at 505K (450°F). Similar edge cracking was found in the specimens aged at 450K (350°F) after 10,000 hours. The degree of edge cracking in these 6 ply laminates was not severe.

Results of the weight change measurements are presented in Tables 11 and 12. At 450K (350°F) weight changes were small with the maximum being a loss of 1.5 percent after 10,000 hours. At 505K (450°F), however, significant weight loss occurred after 5,000 hours (6 percent) and increased to about 9 percent after 10,000 hours. Results of the reduced pressure tests have not been completed at this time.

Residual tensile strength data are tabulated in Tables 13 and 14. In contrast to the weight change data there was not much difference in the tensile results for the two aging temperatures. The difference that was observed was a slightly higher retention of the tensile strength for the specimens aged at the higher temperature. This is in contrast to thermal aging effects measured on several other composite systems where higher aging temperatures have resulted in increased loss in strength.

Samples of Celion 6000/LARC-160 G/PI in the unexposed condition and after 5000 and 10,000 hours of exposure were mounted, polished, and examined using optical and scanning electron microscopes. At lower magnifications, the degree of microcracking and relief polishing at the graphite fibers could be seen to be related to both the temperature and length of time of aging (increasing with both increasing temperature and time). At higher magnification, evidence of oxidation, similar in nature to that first observed in the A-S/3501 G/E system was found. When the polyimide resin matrix oxidized, it was more prone to crumble and resulted in an increased amount of relief polishing around the individual fibers. After 10,000 hours of aging at both temperatures, considerable oxidation had occurred in the outer plies but almost none in the center plies. This would be expected for an oxidation mechanism where attack begins at the outer surfaces and proceeds inward. Careful examination of the polished specimens also revealed an effect of temperature on oxidation where the degree of relief polishing around the graphite fibers was slightly greater at 505K (450°F) than at 450K (350°F). This oxidation effect was not observed for the HT-S/710 G/PI system evaluated during Phases I and II.

3.2 Flight Simulation Testing. Progress of flight simulation testing of the Celion 6000/LARC-160 G/PI is shown in Table 5. Except for the two specimen failures soon after the start of testing and before the two load reductions (see Progress Report, 1 June 1982) there have been no problems with the Phase III flight simulation tests. Over 7500 hours of exposure have been completed. The first set of residual strength evaluations will be conducted at the 10,000 hour mark.

4.0 PHASE IV

The 10,000 hour thermal age of Celion 6000/LARC-160 graphite/polyimide and A-S/3501 graphite/epoxy has been completed. Post exposure testing is in progress. The results will be presented in the next report.

Table 1. Thermal Aging Data for $[0°]_6$ B/Al Aged in One Atmosphere Air and Tested at 297K (75°F) - Longitudinal Test Direction

Aging Temperature K	Aging Temperature (°F)	Aging Time (hr)		Tensile Strength MN/m^2	Tensile Strength (ksi)
450	350	Baseline Avg		1,450	210
		5,000		1,320	191
				1,230	179
				1,070	155
			avg	1,210	175
		10,000		1,010	146
				986	143
				869	126
			avg	955	138
505	450	25,000		862	125
				896	130
				1,430	208
			avg	1,060	154
		40,000		1,450	210
				1,340	195
				1,230	179
			avg	1,340	195
561	550	5,000		841	122
				855	124
				889	129
			avg	862	125
		10,000		855	124
				703	102
				786	114
			avg	781	113
		25,000		1,360	198
				1,510	219
				1,180	171
			avg	1,350	196
		40,000		917	133
				1,230	179
				820	119
			avg	990	144
700	800	5,000		327	47.4
				631	91.5
				315	45.7
			avg	424	61.5
		10,000		263	38.1
				320	46.4
				318	46.1
			avg	300	43.5

Table 2. Thermal Aging Data for [0° ± 45°]$_s$ Crossplied B/Al Aged in One Atmosphere Air And Tested at 297K (75°F) - Longitudinal Test Direction

Aging Temperature K	Aging Temperature (°F)	Aging Time (hr)		Tensile Strength MN/m^2	Tensile Strength (ksi)
450	350	Baseline Avg		516	74.8
		5,000		430	62.3
				467	67.7
				535	77.6
			avg	477	69.2
		10,000		459	66.6
				444	64.4
				428	62.1
			avg	444	64.4
505	450	25,000		573	83.1
				585	84.9
				584	84.7
			avg	581	84.2
		40,000		584	84.7
				593	86.0
				574	83.3
			avg	584	84.7
561	550	5,000		276	40.1
				251	36.4
				257	37.3
			avg	261	37.9
		10,000		184	26.7
				214	31.1
				210	30.4
			avg	203	29.4
		25,000		576	83.6
				574	83.2
				552	80.0
			avg	567	82.3
		40,000		525	76.1
				518	75.1
				558	80.9
			avg	534	77.4
700	800	5,000		168	24.4
				185	26.8
				198	28.7
			avg	184	26.6
		10,000		142	20.6
				143	20.7
				154	22.3
			avg	146	21.2

Table 3. Thermal Aging Data for $[0°]_6$ B/Al Aged in One Atmosphere Air and Tested at 297K (75°F) - Transverse Test Direction

Aging Temperature K	Aging Temperature (°F)	Aging Time (hr)		Tensile Strength MN/m^2	Tensile Strength (ksi)
450	350	Baseline Avg		79.3	11.5
		5,000		159	23.1
				143	20.7
				116	16.8
			avg	139	20.2
		10,000		104	15.1
				93.8	13.6
				121	17.5
			avg	106	15.4
505	450	25,000		119	17.2
				109	15.8
				103	15.0
			avg	110	16.0
		40,000		105	15.2
				103	14.9
				101	14.7
			avg	103	14.9
561	550	5,000		98.6	14.3
				102	14.8
				104	15.1
			avg	102	14.7
		10,000		108	15.7
				74.5	10.8
				75.2	10.9
			avg	85.9	12.5
		25,000		91.7	13.3
				93.1	13.5
				91.0	13.2
			avg	91.7	13.3
		40,000		91.0	13.2
				86.2	12.5
				99.3	14.4
			avg	92.2	13.4
700	800	5,000		104	15.1
				101	14.7
				94.5	13.7
			avg	100	14.5
		10,000		80.0	11.6
				76.5	11.1
				100	14.5
			avg	85.5	12.4

Table 4. Thermal Aging Data for $[0°]_6$ B/Al Aged in One Atmosphere Air and Tested at 297 K (75°F) - Interfiber Shear in Longitudinal Direction

Aging Temperature K	Aging Temperature (°F)	Aging Time (hr)		Tensile Strength MN/m^2	Tensile Strength (ksi)
450	350	Baseline Avg		93.1	13.5
		5,000		82.0	11.9
				93.1	13.5
				109	15.8
			avg	94.7	13.7
		10,000		109	15.8
				100	14.5
				108	15.7
			avg	106	15.3
505	450	25,000		88.2	12.8
				87.6	12.7
				89.6	13.0
			avg	88.2	12.8
		40,000		91.0	13.2
				86.9	12.6
				78.6	11.4
			avg	85.5	12.4
561	550	5,000		85.5	12.4
				93.8	13.6
				91.7	13.3
			avg	90.3	13.1
		10,000		97.2	14.1
				91.7	13.3
				91.0	13.2
			avg	93.3	13.5
		25,000		51	7.4
				50	7.2
				51	7.4
			avg	50	7.3
		40,000		47	6.8
				52	7.6
				46	6.6
			avg	48	7.0
700	800	5,000		42.1	6.1
				77.2	11.2
				79.3	11.5
			avg	66.2	9.6
		10,000		71.7	10.4
				18.6	2.7
				24.8	3.6
			avg	38.4	5.6

Table 5. Total Exposure Time in Hours for Long Term Flight Simulation Specimens

	Setup Number and Material System							
Date	1. B/Al	2.* G/PI	3.* G/PI	4.** G/PI	5.** G/PI	6. B/E-G/E	8. B/E-G/E	10. B/Al
1-2-79	14,942	15,784	17,167			8,989	9,453	17,091
3-5-79	15,494	16,651	18,127			9,946	10,428	17,901
6-4-79	17,003	18,204	19,550			11,683	11,974	19,493
1-21-80	18,066	19,863	20,835			13,422	13,527	20,957
6-2-80	19,947	21,332	23,004			15,547	15,662	20,957
12-23-80	23,729	25,365	27,338			19,740	19,889	23,345
2-9-81	24,249	25,871	27,662			20,241	20,409	23,880
6-1-81	25,981	27,890	29,923			22,405	22,691	26,148
10-19-81	27,560		31,692	66	13	24,122	24,549	27,893
4-19-82	27,560		31,911	334	171	24,425	24,862	28,206
8-9-82	28,950		33,829	2,391	1,974	26,468	***	29,719
12-20-82	30,679		35,912	4,397	3,952	28,634		31,316
4-25-83	32,324		38,437	6,984	6,547	31,246		33,972
6-6-83	33,296		39,398	7,964	7,526	32,227		34,931

* HT-S/710 Graphite/Polyimide

** Celion 6000/LARC-160 Graphite/Polyimide

*** Specimens removed after 25,000 hours.

Table 6. Residual Strength Test Plan for Phase II B/E and G/E After 25,000 Hours of Flight Simulation Testing

Material System	Flight Simulation Specimen Type	Test Type	Temperature K	Temperature (°F)	Number of Specimens
B/E	$[0° \pm 45°]_s$ Unnotched	Tensile	297	75	3
		Fatigue			6
		Compressive			4
		Shear			4
G/E	$[0° \pm 45°]_s$ Unnotched	Tensile	297	75	3
		Fatigue			6
		Compressive			4
		Shear			4

Table 7. Strength and Modulus Properties of $[0° \pm 45°]_s$ B/E at 297K (75°F) Before and After 10,000 and 25,000 Hours of Flight Simulation Exposure

Specimen Number	Flight Simulation Specimen Number		Strength MN/m^2	Strength (ksi)	Modulus GN/m^2	Modulus (Msi)
Unnotched Tensile:	10,000 hr					
A931-1	AC93-1		492	71.3	79.3	11.5
-2	-1		457	66.3	66.9	9.7
-3	-1		551	79.9	69.6	10.1
-4	-1		468	67.9	70.3	10.2
-5	-1		487	70.6	68.3	9.9
-6	-1		527	76.4	71.7	10.4
A935-4	-5		533	77.3	71.7	10.4
-6	-5		474	68.7	63.4	9.2
		Avg	498	72.3	70.3	10.2
Unnotched Tensile:	25,000 hr					
A941-1	AC94-1		447	64.9	61	8.8
-2	-1		482	69.9	59	8.6
-3	-1		483	70.1	61	8.9
		Avg	471	68.3	60	8.8
Baseline (Phase II Material)		Avg	531	77.0	70.3	10.2

Table 8. Compressive and Short Beam Shear Strength of $[0° \pm 45°]_s$ B/E at 297K (75°F) Before and After 10,000 and 25,000 Hours of Flight Simulation Exposure

Specimen Number	Flight Simulation Specimen Number		Strength MN/m^2	Strength (ksi)	Modulus GN/m^2	Modulus (Msi)
Compressive:	10,000 hours					
A9C-8	AC93-3		1,160	169	69.0	10.0
-9	-3		1,230	179	70.3	10.2
-10	-3		1,170	170	71.0	10.3
-11	-3		1,170	170	69.6	10.1
		Avg	1,190	172	70.3	10.2
Compressive:	25,000 hours					
A9C-12	AC94-3		1,040	151	68	9.9
-13	-3		924	134	66	9.5
-14	-3		1,090	158	67	9.7
-15	-3		1,090	158	68	9.9
		Avg	1,030	150	67	9.8
Baseline (Phase I Material)			1,540	223	102	14.8
Short Beam Shear:	10,000 hours					
A9S-1	AC93-5		66	9.5		
-2	-5		65	9.4		
-3	-5		65	9.4		
-4	-5		68	9.9		
		Avg	66	9.6		
Short Beam Shear:	25,000 hours					
A9S-5	AC94-2		45	6.5		
-6	-2		48	7.0		
-7	-2		45	6.5		
-8	-2		41	5.9		
		Avg	45	6.5		
Baseline (Phase I (Material)		Avg	66	9.5		

Table 9. Strength and Modulus Properties of [0° ± 45°]$_s$ G/E at 297K (75°F) Before and After 10,000 and 25,000 Hours of Flight Simulation Exposure

Specimen Number	Flight Simulation Specimen Number		Strength MN/m^2	Strength (ksi)	Modulus GN/m^2	Modulus (Msi)
Unnotched Tensile: 10,000 hours						
B931-1	BC93-1		747	108.3	61	8.8
-2	-1		661	95.9	61	8.9
-3	-1		686	99.5	59	8.6
-4	-1		587	85.1	61	8.9
-5	-1		705	102.3	59	8.5
-6	-1		554	80.4	56	8.1
B935-4	-5		492	71.4	52	7.5
-6	-5		609	88.3	52	7.6
		Avg	630	91.4	58	8.4
Unnotched Tensile: 25,000 hr						
B941-1	BC94-1		632	91.7	46	6.6
-2	-1		647	93.8	44	6.4
-3	-1		583	84.6	45	6.5
		Avg	621	90.0	45	6.5
Baseline Phase II Material)		Avg	490	71.1	51	7.4

Table 10. Compressive and Short Beam Shear Strength of $[0° \pm 45°]_s$ G/E at 297K (75°F) Before and After 10,000 and 25,000 Hours of Flight Simulation Exposure

Specimen Number	Flight Simulation Specimen Number		Strength MN/m²	(ksi)	Modulus GN/m²	(Msi)
Compressive:	10,000 hr					
B9C-3	BC93-3		551	79.9	46	6.7
-4	-3		527	76.5	43	6.3
-5	-3		576	83.6	46	6.6
-6	-3		576	83.5	43	6.3
		Avg	558	80.9	45	6.5
Compressive:	25,000 hr					
B9C-7	BC94-3		620	89.9	51	7.4
-8	-3		622	90.2	50	7.3
-9	-3		574	83.2	50	7.2
-10	-3		618	89.6	50	7.2
		Avg	608	88.2	50	7.3
Baseline (Phase I Material)		Avg	570	82.7	46	6.6
Short Beam Shear:	10,000 hr					
B9S-1	BC93-5		66	9.5		
-2	-5		61	8.9		
-3	-5		63	9.2		
-4	-5		62	9.0		
		Avg	63	9.2		
Short Beam Shear:	25,000 hr					
B9S-5	BC94-2		68	9.8		
-6	-2		68	9.8		
-7	-2		68	9.9		
-8	-2		70	10.2		
		Avg	68	9.9		
Baseline (Phase I Material)		Avg	74	10.7		

Table 11. Thermal Aging Data (Weight Changes) for Celion 6000/LARC-160 G/PI Aged in 0.10 MN/m^2 (14.7 psi) Air

Aging Temperature K	(°F)	Aging Time (hr)	Weight Change gm	Percent
450	350	500	+0.006	+0.2
			+0.008	+0.2
			+0.006	+0.2
				Avg +0.2
		1,000	+0.004	+0.1
			+0.005	+0.1
			+0.006	+0.2
				Avg +0.1
		5,000	0.000	0.0
			-0.001	0.0
			-0.001	0.0
				Avg 0.0
		10,000	-0.056	-1.6
			-0.045	-1.3
			-0.063	-1.7
				Avg -1.5

Table 12. Thermal Aging Data (Weight Changes) for Celion 6000/LARC-160 G/PI Aged in 0.10 MN/m^2 (14.7 psi) Air

Aging Temperature K	(°F)	Aging Time (hr)	Weight Change gm	Percent
505	450	500	-0.02	-0.6
			-0.02	-0.6
			-0.02	-0.5
				Avg -0.6
		1,000	-0.03	-0.7
			-0.03	-0.8
			-0.03	-0.8
				Avg -0.8
		5,000	-0.21	-5.9
			-0.21	-5.8
			-0.19	-5.5
				Avg -5.7
		10,000	-0.31	-8.7
			-0.32	-8.9
			-0.31	-8.7
				Avg -8.8

Table 13. Thermal Aging Data for $[0° + 45°]_s$ Celion 6000/LARC-160 G/PI Aged in 0.10 MN/m^2 (14.7 psi) Air

Aging Temperature K	(°F)	Test Temperature K	(°F)	Aging Time (hr)		Tensile Strength MN/m^2	(ksi)
450	350	450	350	Baseline Average		696	101
				500		597	86.6
						596	86.5
						628	91.1
					Avg	607	88.1
				1,000		518	75.2
						564	81.8
						578	83.8
					Avg	553	80.3
				5,000		506	73.4
						626	90.8
						550	79.8
					Avg	561	81.3
				10,000		482	69.9
						423	61.4
						496	72.0
					Avg	467	67.8

Table 14. Thermal Aging Data for $[0° + 45°]_s$ Celion 6000/LARC-160 G/PI Aged in 0.10 MN/m^2 (14.7 psi) Air

Aging Temperature K	(°F)	Test Temperature K	(°F)	Aging Time (hr)		Tensile Strength MN/m^2	(ksi)
505	450	450	350	Baseline Avg		696	101
				500		609	88.3
						663	96.2
						685	99.4
					Avg	652	94.6
				1,000		667	96.8
						579	84.0
						607	88.1
					Avg	618	89.6
				5,000		571	82.8
						562	81.5
						566	82.1
					Avg	566	82.1
				10,000		514	74.6
						516	74.8
						510	74.0
					Avg	513	74.5